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FINAL TECHNICAL REPORT

NASA GRANT #NAG8-915

**THE LIFE CYCLES OF INTENSE CYCLONIC AND ANTICYCLONIC
CIRCULATION SYSTEMS OBSERVED OVER OCEANS**

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1. Introduction

This report presents a summary of research accomplished over the past four years under the sponsorship of NASA grant #NAG8-915. The details of the scientific findings are contained in the eight journal papers, one Ph.D. thesis, four M.S. theses, and six conference preprint papers that represent work either directly supported or strongly influenced by this grant (see listings in section 4). Results were also presented in five additional oral presentations.

2. Project objectives

2.1. Extension of previous work

Building on previously funded NASA grants, this part of the project focused on the following specific goals relative to cyclone/anticyclone systems:

- (a) the jet streak link between block formation and upstream cyclone activity;
- (b) the role of northward warm air advection in block formation;
- (c) the importance of cooperative participation of several forcing mechanisms during explosive cyclone development; and
- (d) the significance of the vertical distribution of forcing processes during cyclone/anticyclone development.

2.2. New initiatives

The previous work of the PI dealt exclusively with the development phases of the cyclone and anticyclone cases examined. This part of the present project included diagnoses of the maintenance and decay phases of the several new cases studied.

3. Brief summary of results

Consistent with the grant title, the focus of much of the research was cyclone and anticyclone cases over oceanic regions. However, in addition, two studies were done (King et al., 1995; Rolfson and Smith, 1996) for continental cases to provide comparison with the marine cases.

In their blocking climatology study Lupo and Smith (1995a) reveal that for a set of 63 blocking episodes each episode was preceded by an upstream cyclone development, often explosive, with cyclogenesis commencing 36-72 h before block onset and 10° to 50° longitude upstream from the position of the block at onset. Furthermore, a 300 mb jet maximum appeared prior to the onset of blocking between the blocking ridge and the upstream 500 mb trough in each of the 63 cases.

The case study reported in Lupo and Smith (1995b) confirms that block formation was largely forced by anticyclonic vorticity advection and was maintained as long as the jet maximum was favorably located. Decay then ensued when favorable upstream cyclone activity and jet maxima were no longer present. At that point temperature advection became an important decay mechanism. During other periods, temperature advection often acted to intensify the block, but was less significant than the vorticity advection influence.

The cyclone studies (Rausch and Smith, 1996; Rolfson and Smith, 1996) reveal that cyclogenesis occurs as a result of the cooperative forcing of cyclonic vorticity advection and warm air advection, both of which maximize in the upper troposphere/lower stratosphere, and latent heat release. Furthermore, strong development is marked by secondary warm advection at lower levels. This is significant because an analysis of the Zwack-Okossi equation used for these

diagnoses reveals that warming is a more effective cyclogenetic mechanism if located lower in the troposphere. A complementary study of surface anticyclone development (King, et al., 1995) shows that the same advection processes, although weaker and of opposite sign, are responsible for anticyclogenesis. In both the cyclone and anticyclone cases decay is marked by a general decrease in all forcing processes as the wave system occludes and by a change in temperature advection (colder for cyclones, warmer for anticyclones) in the lower troposphere.

Finally, it is appropriate to comment on the quality of the NASA data analyses used, which were 4° lat x 5° lon or 2° lat x 2.5° lon fields provided by the NASA Goddard Laboratory for Atmospheres (GLA). This is an especially important consideration since the focus of the study was oceanic regions. Since such regions are data-sparse with regard to conventional, land-based data platforms, the availability of a high quality model-based analysis scheme enhanced by satellite-based data is crucial. Lamberty and Smith (1993) discuss the importance of satellite data in GLA analyses over the Atlantic Ocean. For this project the PI and his students experienced little difficulty in utilizing GLA analysis fields to yield realistic and meaningful diagnoses of cyclone and anticyclone dynamics.

4. Publications and presentations

4.1. Journal papers

Lamberty, G.L., and P.J. Smith (1993): A Study of the Influence of Satellite Data on GLA Analyses Over the Atlantic Ocean During a Period of Blocking Anticyclone Development. Monthly Weather Review, 121, 1881-1891.

- Lupo, A.R., and P.J. Smith (1995a): Climatological Features of Blocking Anticyclones in the Northern Hemisphere. Tellus, 47A, 439-456.
- _____, and _____ (1995b): Planetary and Synoptic-Scale Interactions During the Life Cycle of a Mid-Latitude Blocking Anticyclone Over the North Atlantic. Tellus, 47A, 575-596.
- King, M.L., P.J. Smith, and A.R. Lupo (1995): A Diagnosis of the Development of a Winter Anticyclone Over North America. Monthly Weather Review, 123, 2273-2284.
- Rausch, R.L.M., and P.J. Smith (1996): A Diagnosis of a Model-Simulated Explosively Developing Extratropical Cyclone. Monthly Weather Review, 124, 875-904.
- Rolfson, D.M., and P.J. Smith (1996): A Composite Diagnosis of Synoptic-Scale Extratropical Cyclone Development Over the United States. Monthly Weather Review, 124, 1084-1099.
- Lupo, A.R., and P.J. Smith (1996): The Interactions Between a Mid-Latitude Blocking Anticyclone and a Synoptic-Scale Cyclone in the Northern Hemisphere Summer Season. Submitted to Quarterly Journal of the Royal Meteorological Society.
- Vasilj, J.M., and P.J. Smith (1996): A Comparison of Extended and Quasigeostrophic Dynamics for a Case of Low Rossby Number Extratropical Cyclone Development. Submitted to Monthly Weather Review.

4.2. Theses

Ph.D.

Anthony R. Lupo, 1995: The Interactions Between Mid-Latitude Blocking Anticyclones and Synoptic-scale Cyclones in the Northern Hemisphere.

M.S.

Melinda L. Hunter, 1993: A Diagnosis of the Development of a Winter Anticyclone Over North America.

Robert L.M. Rausch, 1994: A Diagnosis of a Model-Simulated Explosively Developing Extratropical Cyclone.

Donald M. Rolfson, 1994: A Diagnosis of Extratropical Cyclone Developments Over the United States.

James M. Vasilj, 1995: A Comparison of Generalized and Quasigeostrophic Forcing During Two Extratropical Cyclone Developments.

4.3. Conference preprints

Lupo, A.R., P.J. Smith, and R.J. Oglesby (1993): Climatological Features of Blocking Anticyclones. Proceedings of the 17th Stanstead Seminar, June 13-18, 1993, Lennoxville, Quebec, Canada.

_____, and _____ (1994): Climatological Features of Blocking Anticyclones I: An Investigation of Observed Mid-Latitude Blocking Characteristics in the Northern Hemisphere. Preprints of the 6th Conference on Climate Variations, January 24-28, 1994, Nashville, TN.

_____, and _____ (1994): The Interaction Between a Mid-Latitude Blocking Anticyclone and the Precursor Cyclone Over the North Atlantic. Preprints of the Symposium on the Life Cycles of Extratropical Cyclones, Vol. II, Bergen, Norway, June 27 - July 1, 1994.

Smith, P.J., and A.R. Lupo (1994): A Diagnosis of the Life Cycle of a Marine Cyclone System. Preprints of the Symposium on the Life Cycles of Extratropical Cyclones, Vol. II, Bergen, Norway, June 27 - July 1, 1994.

Rausch, R.L.M., and P.J. Smith (1994): Diagnosis of a Model Simulation of an Explosively Developing Extratropical Cyclone. Preprints of the 10th Conference on Numerical Weather Prediction, July 18-22, Portland, Oregon.

Rolfson, D.R. and P.J. Smith (1995): A Diagnosis of Twelve Extratropical Cyclone Developments Over the United States. Preprints of the 14th Conference on Weather Analysis and Forecasting, January 15-20, Dallas, TX.

4.4. Other oral presentations

Conferences

Smith, P.J.: An Updated Conceptual Model of Surface Cyclone Evolution. Ninth Extratropical Cyclone Workshop, 3-7 December, 1995, Monterey, CA.

_____: The Dynamics of an Early Winter, Explosive Cyclone Development. 2nd Winter Weather Workshop, February 15-16, 1996, Madison, WI.

The Influence of Latent Heat Release on Extratropical Cyclone Development.

Workshop on Links Between Variations in Solar Activity, Atmospheric Conductivity, and Clouds. Institute of Geophysics and Space Physics, Los Alamos National Laboratory. June 20-21, 1996.

Seminars

Smith, P.J.: Diagnosing Synoptic-Scale Development - The Zwack-Okossi Equation. National Meteorological Center, March 24, 1994.

_____: The Diagnosis of a Model-Simulated Explosively Developing Extratropical Cyclone. Ecole Nationale de la Meteorologie, Toulouse, France, June 23, 1994.

5. Concluding remark

Speaking on behalf of himself and the students involved in this project, the PI wishes to thank NASA for the support of research and graduate education represented by this grant.